FIREBALL CALCULATIONS

SHOT WRANGELL

OPERATION HARDTACK, PHASE II

PROJECT 15.1



Report No. B-2064 4 March 1960

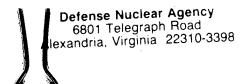
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Prepared by (Lampbell J. E. Campbell

Approved by

EDGERTON, GERMESHAUSEN & GRIER, INC. Boston, Mass. Santa Barbara, Calif. Las Vegas, Nev.







ISST

29 May 1996

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER ATTENTION: OCD/MR. BILL BUSH

SUBJECT: Documents for DTIC System

There is no record of your office receiving the following reports:

EGG-B-2064 (4 March 1960) Fireball Calculations Shot Wrangell Operation Hardtack Phase II, Project 15.1

EGG-B-2063 (4 March 1960) Fireball Calculations Shot Humboldt Operation Hardtack Phase II Project 15.1

Both documents are now approved for public release.

Therefore, we are transmitting copies for inclusion into the DTIC system, if not found there.

Enclosure: A/S

ARDITH JARRETT Chief, Technical Support

DTIC QUALITY INSPECTED 4

FIREBALL CALCULATIONS - SHOT WRANGELL

1.0 INTRODUCTION

Shot Wrangell was a 1500-foot balloon shot sponsored by LRL and detonated on 22 October 1958 in Area B-Fa of the Nevada Test Site at 0850 PST.

The fireball yield was $67.3 \text{ tons} \pm 5.0 \text{ tons}$.

2.0 CAMERA INSTRUMENTATION AND OPERATION

Photographic coverage of fireball growth was provided by four high-speed Eastman cameras, two each at Station F-362 (6 x 6 No. 2) and Station F-369 (6 x 6 No. 3). In addition, two Rapatronic cameras were located at each of these stations to record early fireball growth.

Three Eastman cameras and three Rapatronics provided good records. The remaining Eastman and Rapatronic, because of malfunctions, did not provide records suitable for analysis.

The station locations, together with the burst location, are shown in Figure 1. Figure 2 contains the Survey Data.

3.0 RESULTS

Application of phi-comparison (EG&G Report No. B-1869) for Shot Wrangell indicates a yield of $67.3 \text{ tons} \pm 5.0 \text{ tons}$.

An air density of 1.057 grams per liter was used in the yield calculations, based on a pressure of 863 millibars, a temperature of 11.1° C, and a relative humidity of 13 percent at the height of the device at shot time.

The following table shows the Wrangell yield as obtained by a phi-comparison to various other low-yield devices:

Comparison Shot		Wrangell Yield Tons
Air Drop		
Wasp		66.74
Buster Baker	•	62.41
Wasp [†]		66.38
Ranger E		63.56
Ranger A		66.73
Osage		71.64
<u> Tower</u>		
Hornet		64.97
Chaves		72.97
Rio Arriba		73.19
Quay		64.44
Humboldt		64.58
<u> Balloon</u>		
Hidalgo	9.5	66.46
		71.03

Diameter-time and phi-time plots are shown in Figures 3 and 4.

The following data sheets are included for each film:

- (a) Photo Plan and Photo Loading Chart
- (b) Camera Data and Calculation Sheet
- (c) Diameter Measurement Sheet
- (d) E-102 Print-Out Sheet of D, t, and \emptyset

Appendix A contains photographic examples of early fireball growth.

The zero-frame times of the Eastman records were determined by comparison with the Rapatronic diameter-time data.

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369	(E#3)				
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				A TEST SI BFA WRANGEL	
				7.5	

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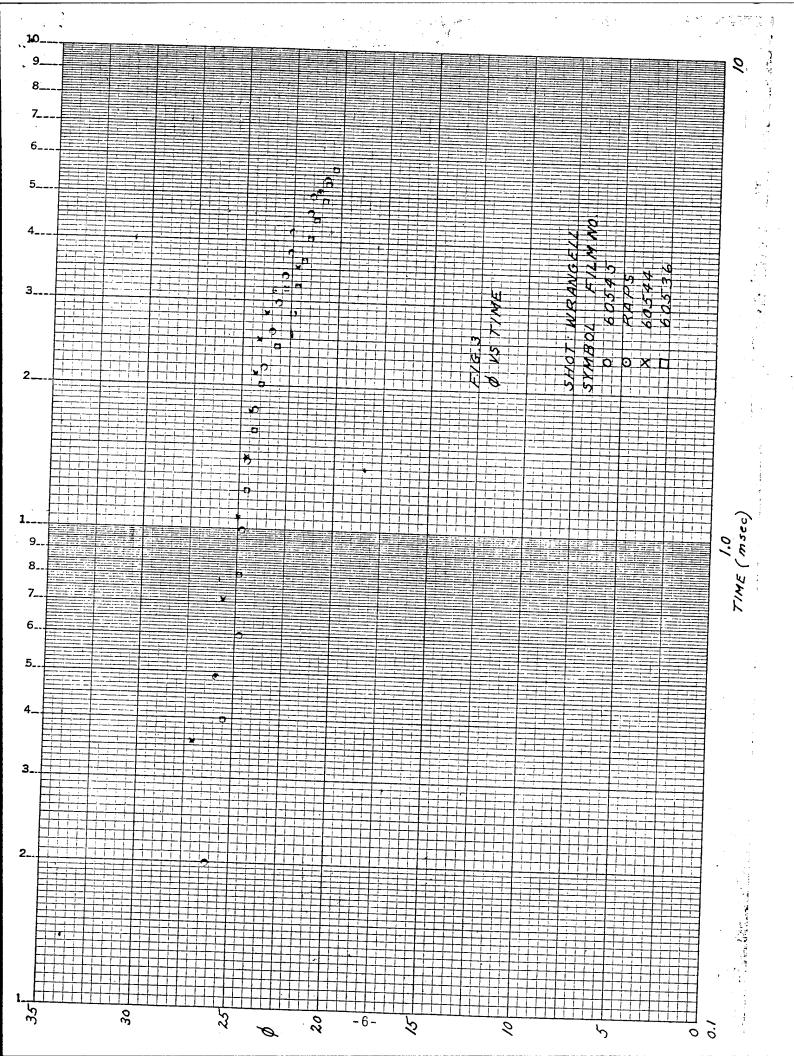
DATE 10/22/58

SURVEY

DATA

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F362 6x6 #1	745844	703948	3091	406	† 12052	1486	12058.8	3675.6	3675.6 29.6847 0.12318	0.12318	88°04'	,10.2
F362 6x6 #2	745825	703946	3090	+425	+ 12054	1487	12061.5	3676.2	28.3624	28.3624 0.12328	87059	7°02'
F369 6x 6 #3	749991	710027	3078	3741	5973	1499	7047.8	2148.2	1.5966	1.5966 0.21269 122004' 12000'	122°04'	12,00,
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Table I

Hardtack Phase II, Wrangell

Average Diameter vs. Time

Time (msec)	Diameter (Meters)
0.5	19.5
1.0	25.0
1.5	29.0
2.0	32.0
2. 5	34.0
3.0	36.0
3. 5	37.5
4.0	38.5
4. 5	39.0
5.0	40.0
5.5	40.5

Table II

Hardtack Phase II - Wrangell

Rapatronic Summary

Station	Film No.	Camera No.	Range (m)	F. L. (mm)	Diameter (m)	Time (ms)
F-362 (6 x 6 No. 2)	60540	R-34	3704. 1	479.03	36.88	3.17
	60539	R-30	3704.1	479.30	19.41	0.49
F-369 (6 x 6 No. 3)	60548	R-4	2196.3	477.82	40.32	5.07
- 9	60547	XR-7	2196.3	481.92	Malfunction	

REMARKS BRG 88°04' EVENT WAANGELL 76N13 10/22/58 11/5/58 GZ STA. BFA DATE POSTED S S. Exp 1229 TILT -0°04' 7°01' FILM ECT DELAY Ħ 98 N/N CZ MARKER TYPE 200 PLAZ 12052 DIFF VOLTS SHUT TIME 1486 1+1-POWER 115 AC MAX PHOTO 4577* **GZ** 746250 716000 Z'S > REMARKS INCLUDES ISON FEET, HEIGHT OF BALLOOM AIMING I 0 OMECT FB 745844 ÷ STATION 3091 TARGET FIELD **≥** ZWN FILTER 254 44 98766 NO-2 SISTANCE OBJECT 12,149.3 A JISTANCE GZ 12, 058.8 FF LENS Z | | | TATION TYPE 6x6 No. TATION NO. F-362 A C. NOM RACK SPD. POS. CAMERA 0009/ FR Š - 10

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			<u> </u>				EVENT WRANGELL	VR ANG	7733			DATE	101	18/58	-
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	7 9	NO.	SIZE	HOLDER	PERF.	₩O.	POS.	NOM. SPO.	P. O. ₹	FILTER	APER	SHUTTER	W/M2	REMARKS	
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EDGERTON, GERMESHAUSEN B. GRIER, INC.

DISTANCE OBJECT 12152.0 FF STATION TYPE 6X6#3 DISTANCE GZ 12 06/5

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DIFF.

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BRG 52°59' EVENT WRANGELL

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EDGERTON, GERMESHAUSEN & GRIER, INC.

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PHOTO PLAN

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BRG 122° 04' EVENT WRANGELL. **DATE** 10 - 22 - 58 **POSTED** GZ STA. BFR ,00

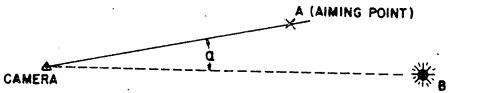
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FORM E-40

EDGERTON, GERMESHAUSEN & GRIER, INC.

FILM NO. 60539 STATION NO. 6-362 TEST WRANGELL CALCULATED BY: JEC CAMERA NO. R-30 EQ. AP.

DATE: 12/2/58

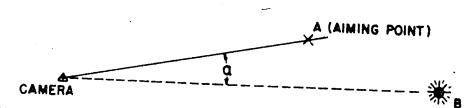


HORIZONTAL PROJECTION

A. R% = CBh cos a cos	$\beta + (H_B - H_C) \sin \beta$	
a= 0°00′	β= 7°02'	HB= 4577 f+
COS a = 1.00000	$\cos \beta = 0.99248$	Hc= 3090 ft
$CB_h = 3676.2 m$	$\sin \beta = 0.12245$	ΔH= 1487 ft= 453.2 m
CB _h $\cos \alpha \cos \beta = 3648.6 m$	$\Delta H \sin \beta = 55.5 m$	R ⁰ / _A = 3704.1m
B. FOCAL LENGTH 4	79.30 mm	

- C. MAGNIFICATION FACTOR (meters/in.) 196.29
- D. ZERO TIME CORRECTION 0.49 msec delay

FILM NO. 60540	STATION NO. 5-362 FO. AP.	Teer	
CAMERA NO. R-34	EQ. AP.	WRANGELL	CALCULATED BY: JEC
	1		DATE: 12/2/58



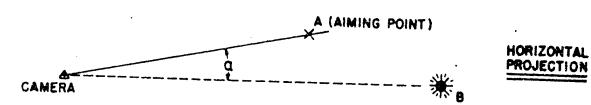
HORIZONTAL PROJECTION

A. R % = CBh cos a cos	$\beta + (H_B - H_C) \sin \beta$	
a= 0°00′	β= 7°02'	N
cos a = /. 00000	$\cos \beta = 0.99248$	H _B = 4577 ft
CB _h = 3676.2 m	$\sin \theta = 0$	$H_{C} = 3090 ft$ $\Delta H = 1487 ft = 453.2 m$
CBh cos a cos $\beta = 3648.6 \text{ m}$	AH sin A - 5-5-5	$R^{0}/_{A} = 3704.1m$
B. FOCAL LENGTH 4	79.03 mm	I G/07.11m

C. MAGNIFICATION FACTOR (meters/in.) 196,41

). ZERO TIME CORRECTION 3.17 msec delay

FILM NO. 60548	A 19 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	17	
	STATION NO. 5-369	TEST WRANGELL	CALCULATED BY: JEC
CAMERA NO. R-4	EQ. AP.	7,10 7,00 2 2 2	230
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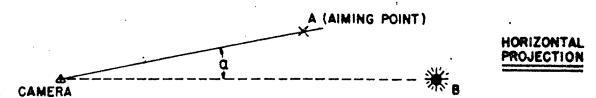


A. $R \%_A = CB_h \cos \alpha \cos$	$\beta + (H_B - H_C) \sin \beta$	
a= 0°00′	β= /2°00'	HB= 4577 ft
COS a = 1.00000	$\cos \beta = 0.97815$	Hc= 3078 ft
$CB_h = 2148.2 m$	sin B = 0 20791	$\Delta H = 1499 ft = 456.9 m$
CBh cos α cos β = 2/0/.3 m	$\Delta H \sin \beta = 95.0 m$	$R^0/_A = 2/96.3 m$
B. FOCAL LENGTH 47	7.82 mm	11.7A (2.770.3 m)

					•	
C.	MAGNIFICATION	FACTOR	(meters/in.)	116.75		

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U.	ZERU	IIME	CORRECTION	5 - 7		, ,
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FILM NO. 60545	STATION NO. 6x6 No. 3	TEST WRANGELL	CALCULATED BY:JEC
	EQ. AP.		DATE: /2/2/58



A. R% = CBh cos a cos	$\beta + (H_B - H_C) \sin \beta$	
a= 0°00'	β= /2° 00'	HB= 4577 ff
COS a = 1.00000	$\cos \beta = 0.97815$	H _C = 3078 ft
$CB_h = 2/48.2 m$	$\sin \beta = 0.20791$	ΔH= 1499 ft = 456.9m
CB _h cos a cos $\beta = 2/0/.3 m$	$\Delta H \sin \beta = 95.0 m$	R ⁰ / _A = 2/96.3 m
B. FOCAL LENGTH 6	3 91 mm (ET1251)	

C. MAGNIFICATION FACTOR (meters/in.) 872.9

ZERO TIME CORRECTION 0.20 msec D. 1/2 frame

DIAMETER MEASUREMENTS

SHOT	WRANGELL
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FILM NO. 60545

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Fr. No.	Mag.	ď	D2.	D ₃	Davg (m)	FLEXON: Dave (m)	t (ms)
0	29.00	0045	0046		13.70		0. 20
1		0068	0066		20, 17		0.60
2		0084	0800	`	24 68		1.00
3		.0093	0092		27.84		1.39
4		0101	0101		30.40		1.79
5		0108	0107		32. 36 34. 16		2.19
6		0113	0114	•	34.16		2 . 5 9
7		0119	0118		37, 02		2 . 98
8		0124	0122		38.08		3.38
9		0128	0125		39.43		3.78
10		0132	0130	•	39.43		4. 18
11		0132	0130		40.48	-	4. 57
12		0135	0134	•	40, 64		4. 97
13		0136	0134	•			5.37
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READ	BY JEC	GGO	TYPED	BY
DATE	11/	4/58	DATE	

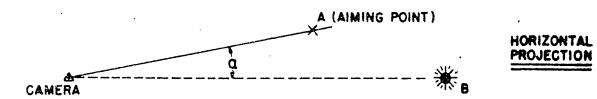
REMARKS:

FIREBALL CALCULATIONS

			FILM	NO	60545
•					
D	†	In D	Int	t ² /5	ф
13.70 2017 24.68 27.84 30.40 32.36 35.67 37.02 38.43 40.48 40.64	.20 100 100 179 199 198 178 178 178 177 177	2.61742 3.00418 3.20592 3.72642 3.41442 3.47693 3.531.09 3.574.36 3.639.76 3.674.60 3.674.60 3.704.83	1.60945 51030 67 52933 58226 78385 95158 1.09189 1.21790 1.32979 1.43038 1.51956 1.60343 1.68079	525303 - 815167 1000031 1140806 1262262 1368260 1463210 1547680 1627692 1702194 1772080 1836433 1899084 1958774	26,0 80 247 43 246 79 244 03 240 83 236 50 233 45 237 43 227 43 227 43 227 47 227 47

SHOT ___

STATION NO. F- 369 FILM NO. 60544 TEST WRANGELL CALCULATED BY: JEC CAMERA NO. E-25 EQ. AP. DATE: 12/2/58



A. $R^{\circ}/A = CB_h \cos \alpha C$	$os \beta + (H_B - H_C) sin \beta$	
a= 0° 00′	β= /2°00'	HB= 4577 ff
cos a = /.00000	$\cos \beta = 0.97815$	Hc= 3078 ft
$CB_h = 2/48.2 m$	$\sin \beta = 0.2079/$	ΔH= 1499ft=456.9m
CB _h cos α cos $\beta = 2/01.3$ n	$\Delta H \sin \beta = 95.0 m$	$R^{0}/A = 2/96.3 m$
B. FOCAL LENGTH	101.8 mm (RA 549)	

- C. MAGNIFICATION FACTOR (meters/in.) 547.9
- ZERO TIME CORRECTION 0.01 msec 0.01 frame D.

SHOT WRANGELL

FILM NO. 60544

Fr. No.	Mag.	D 1	D ₂ .	D ₃	Davg (m)	FLEXOWE Dave (m)	t (ms)
0	48. 15	0090	0092		10.36		0.01
1		0157	0157	,	17.87		0.36
2		0197	0195		22.30		0.71
3		0225	0223		25.49		1.06
4		0247	0248		28 17 30 50		1.42
5 6		0270	0266		32 60	•	1.77
6		0286	0287	•	34.42		2.12
7		0305	0300	•	35.73		2.48
8		0316	0312		36.02		2.83
9		0315	0318	•	36 70		3, 18
10		0320	0325	•			3.54
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REMARKS:

DATE

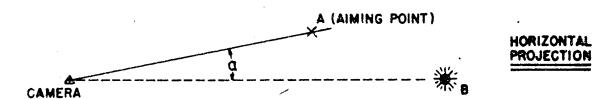
11/4/58

DATE

FIREBALL CALCULATIONS

	SHOT	WRANGELL	FILM NO	60544	
D .	t	In D	Int	† ² /5	ф
10.36 17.87 22.30 25.49 28.17 30.50 32.60 34.42 35.73 36.70	.01 36 71 106 142 177 212 248 283 318	2.33795 2.88317 3.10453 3.23821 3.33820 3.41771 3.48433 3.53868 3.57605 3.58413 3.60284	75070 57103 75137 90818 104022 115688	.1 590 64 6 645 53 8 719 56 10 235 65 11 505 97 12 566 03 14 380 27 15 160 22 15 884 41 16 580 28	65,130 26890 25574 24903 24482 24437 24137 23935 23568 22676 22133

FILM NO. 60536 .	STATION NO. 5-362	TEST WRANGELL	CALCULATED BY: JEC
CAMERA NO. E-34	EQ. AP.		DATE: 12/2/58



A. $R \% = CBh \cos a \cos$	β + (H _B -H _C) sin β	
a= 0°00′	β= 7° 02'	H _B = 4577 ft
cos a = /. 00000	$\cos \beta = 0.99248$	Hc= 3090 ff
CBh = 3676.2 m	$\sin \beta = 0.12245$	ΔH= 1487ft= 453.24m
CBh cos a cos $\beta = 3648.6 m$	$\Delta H \sin \beta = 55.5 m$	$R^{0}/_{A} = 3704.1m$
D FOCAL LENGTH //	(00.540)	

B. FOCAL LENGTH 152.8 mm (RC 540)

C. MAGNIFICATION FACTOR (meters/in.) 615.7

D. ZERO TIME CORRECTION 0.40 msec (0.99 fr)

C117/C11	
SHOT WRANGELL	
WRANGERII.	

FILM NO.	605367	
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	44-	_	_	_		FIAEXON	
Fr. No.	Mag.	D ₁	D ₂ .	D3	Davg (m)	Dave (m)	t (ms)
0	48. 15	0136	0139		17.59		0.40
1		0177	0178		22.70		0.80
2		0204	0207		26.28		1.21
3		0227	0228		29. 10		1.61
4		0245	0248	•	31.53		2.02
5		0253	0261		32.87	u.e	2.42
6		0264	0264		33. 77 35. 11		2.82
7		0275	0274		36, 39		3.23
8		0284	0285		37.41		3.63
9		0292	0293		38.31 38.88		4.04
10		0299	0300		38.88		4.44
11		0301	0307		39.78		4.85
12		0309	0313	•	40, 35		5. 25
13		0315	0316	•	 	*	5, 65
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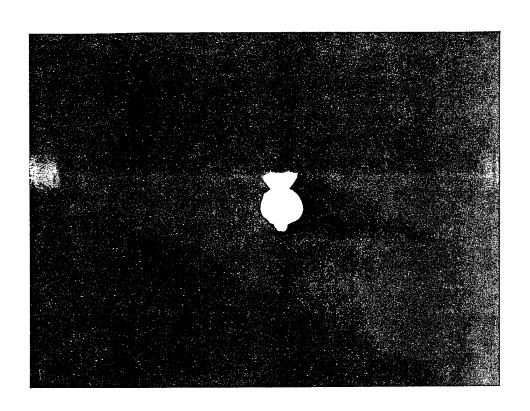
READ	BY GGO	JEC TYPED	BA
DATE	11/4/58	DATE	

REMARKS:

FIREBALL CALCULATIONS

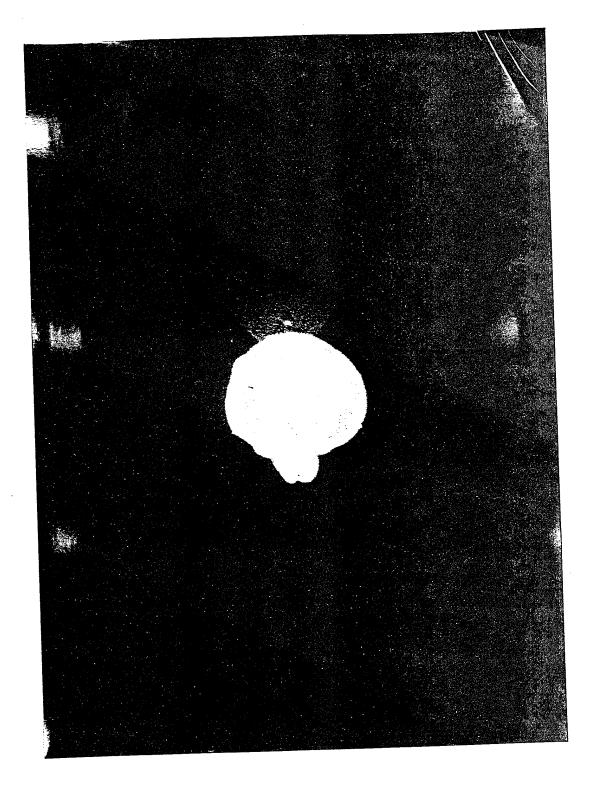
	SHOT	WRANGELL	FILM NO	o. <u>60536</u>	
·		•	DATE		
D .	†	In D	Int	† ² /5	ф
17.79 26.28 29.10 31.87 33.51 3.77 3.77 3.88 3.88 3.88 3.88 3.88 3.88	.400 1160 120 120 120 120 120 120 130 140 150 150 150 150 150 150 150 150 150 15	2.86739 312230 326874 337070 345094 349258 351960 3559436 362201 364578 366056 3683447	.916.21 - 223.11 - 190.56 476.31 703.08 883.69 1036.68 1172.49 1289.29 1396.32 1490.71 1579.00 1658.20 1731.60		253 76 243 18 243 51 240 51 238 00 230 82 223 65 217 27 214 00 211 03 204 92 201 85

APPENDIX A HARDTACK PHASE II, WRANGELL PHOTOGRAPHIC EXAMPLES



Station: F-362 (6 x 6 No. 2)

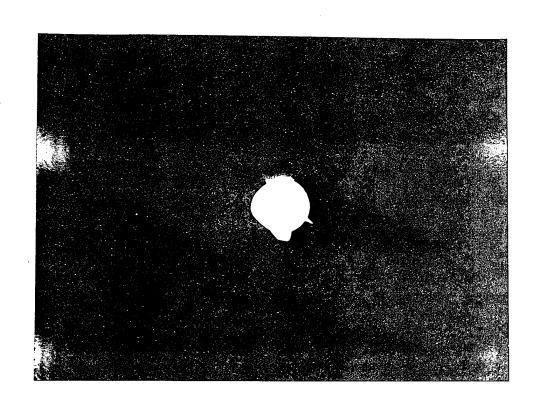
Time: 0.40 msec



Camera: R-30

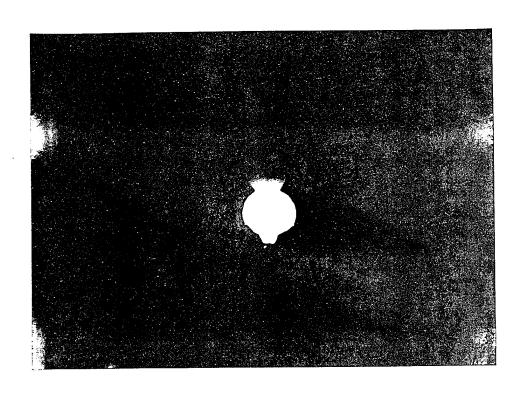
Station: F-362 (6 x 6 No. 2)

Time: 0.49 msec



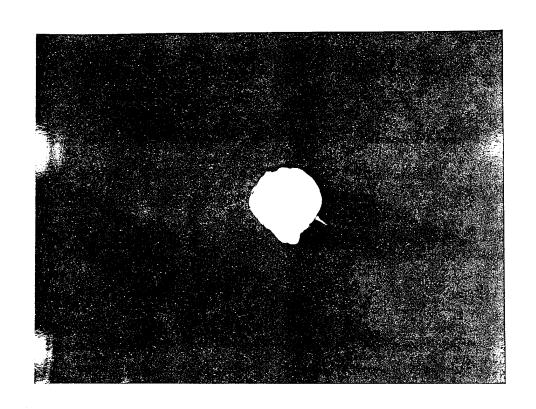
Station: F-369 (6 x 6 No. 3)

Time: 0.71 msec



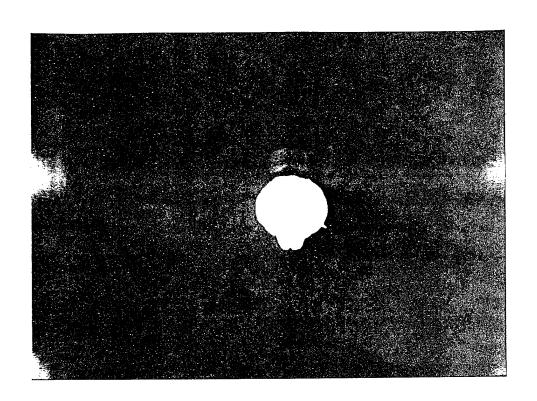
Station: F-362 (6 x 6 No. 2)

Time: 0.80 msec



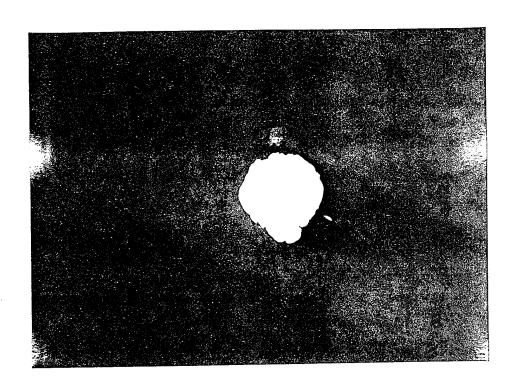
Station: F-369 (6 x 6 No. 3)

Time: 1.42 msec



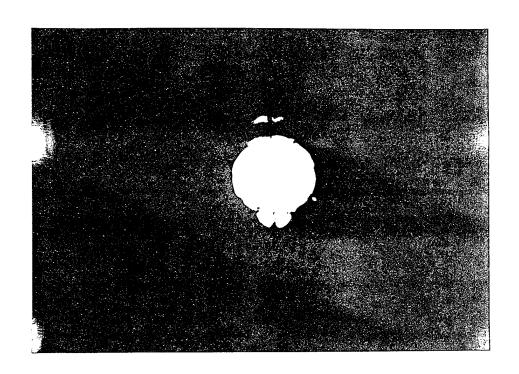
Station: F-362 (6 x 6 No. 2)

Time: 2.02 msec



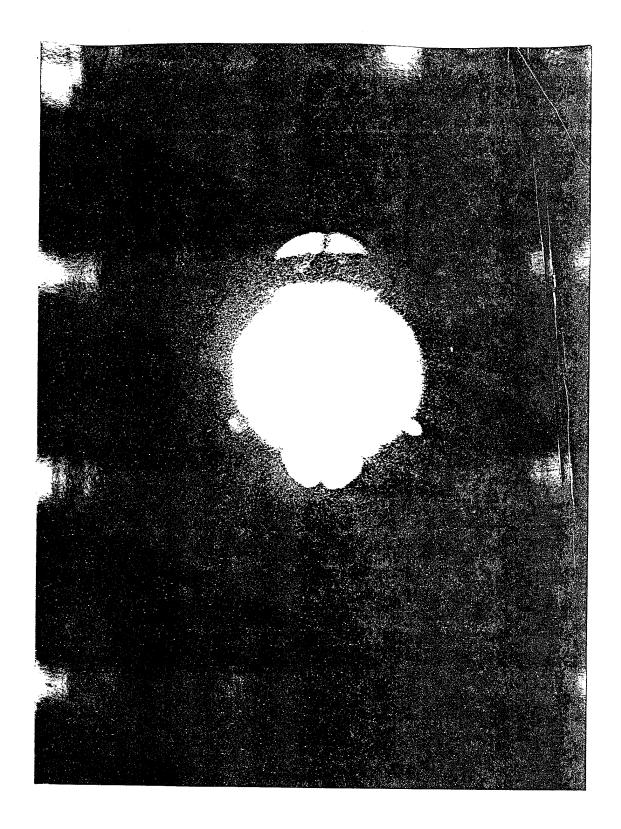
Station: F-369 (6 x 6 No. 3)

Time: 2.48 msec



Station: F-362 (6 x 6 No. 2)

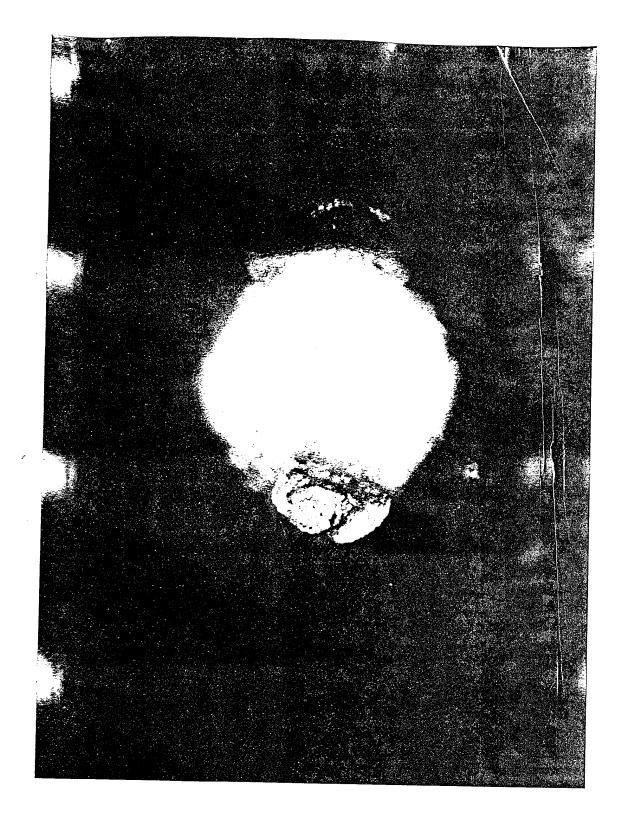
Time: 3.63 msec



Camera: R-34

Station: F-362 (6 x 6 No. 2)

Time: 3.17 msec



Camera: R-4

Station: F-369 (6 x 6 No. 3)

Time: 5.07 msec

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